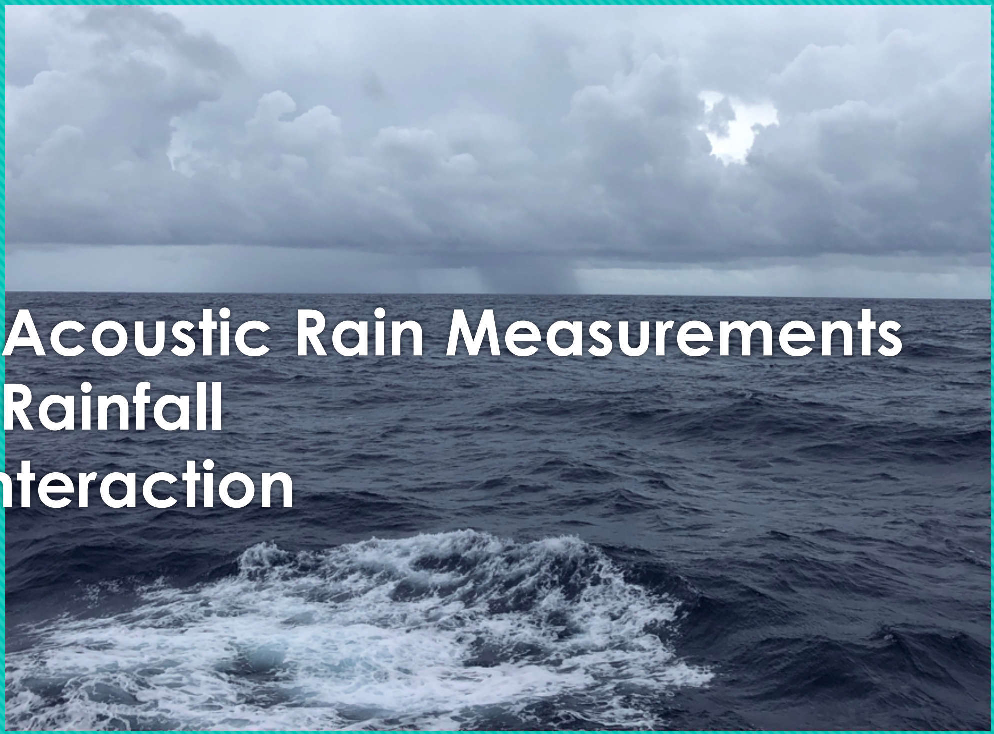
Comparison of Oceanic Acoustic Rain Measurements with Downscaled IMERG Rainfall for the Study of Air-Sea Interaction



Elizabeth J. Thompson: NOAA Earth System Research Lab

Jie Yang: Applied Physics Lab at Univ. of Washington – ***poster tonight!***

Janice Bytheway: NOAA ESRL / CU CIRES

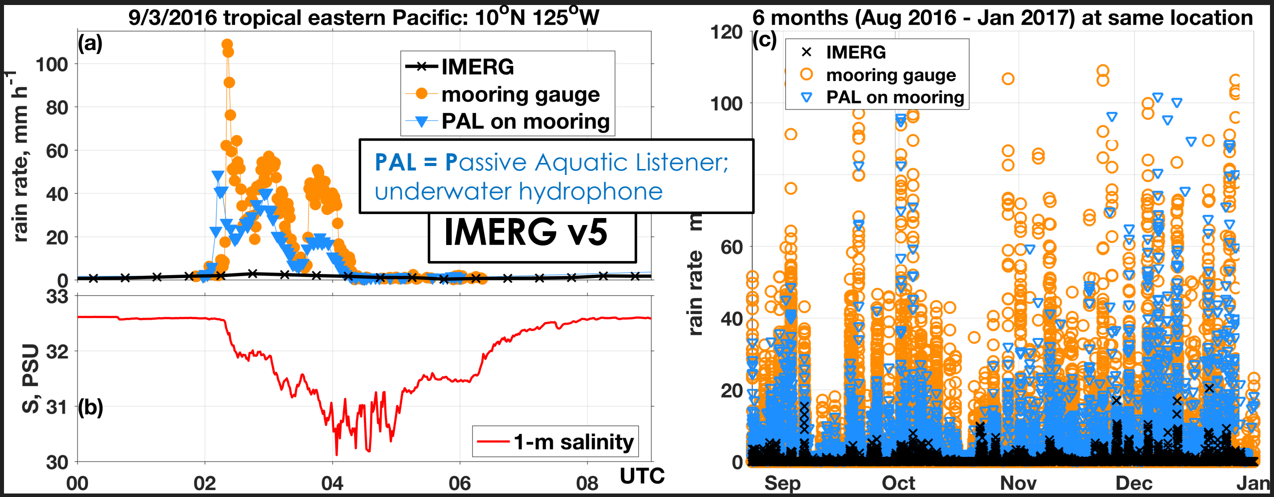
Tom Farrar: Woods Hole Oceanographic Institution

Motivation

freshwater fluxes into ocean produce significant:

1. surface freshening
2. surface heat fluxes
3. surface buoyancy flux

→ determines ocean stability, mixing, heat content, surface energy budget



Motivation

Also relevant for convective parameterizations, high-impact weather, weather monitoring, atmospheric dynamics

A **downscaled version of IMERG** is needed for studies of air-sea interaction, and oceanography because these processes are forced by **instantaneous rain rate**

- IMERG has effective resolution ~ 15-30 km, and rain amounts ~ 30-90 min mean rate
- *Ocean Validation "OV"* is needed for 75% of Earth not covered by GV
- Error characterization is also needed for satellite rain products

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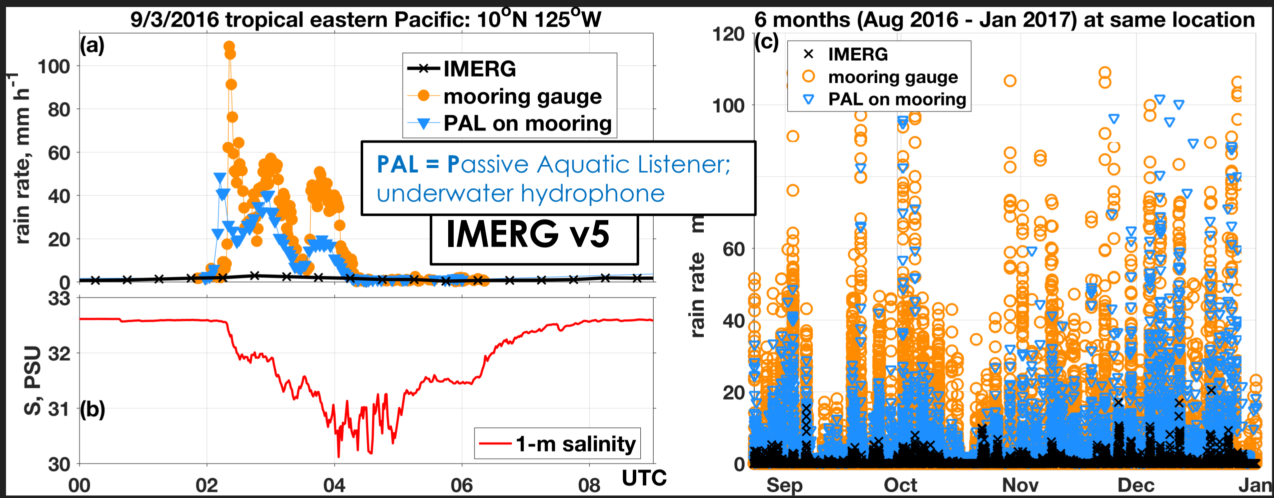
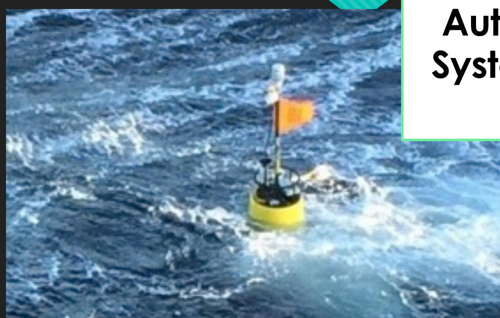
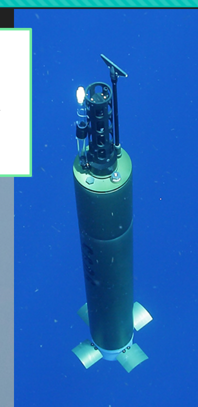
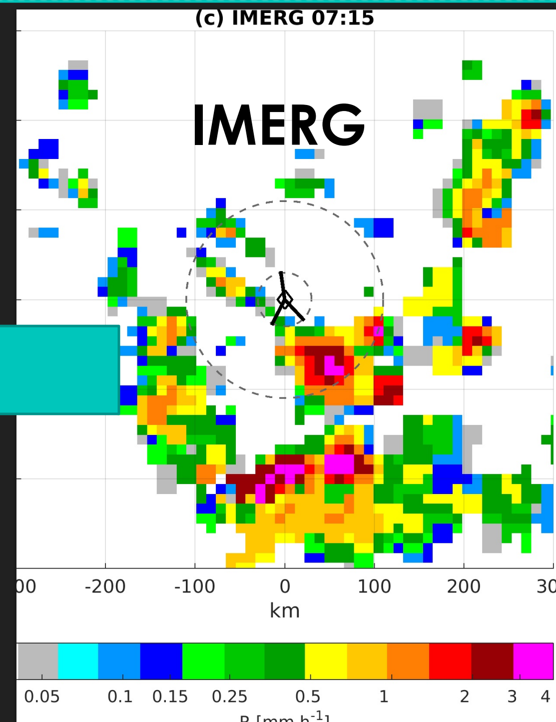


Higher resolution rain information must be *extracted* from IMERG to use remotely-sensed rain data to study air-sea interaction



Autonomous Ocean Observing System → requires a continuous, global rain dataset

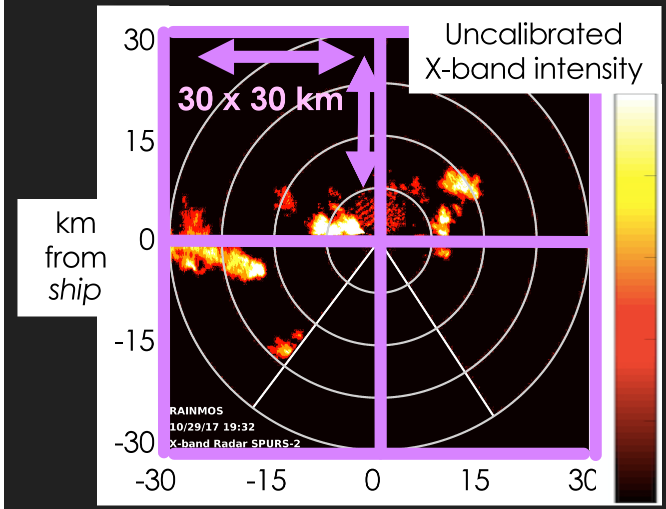




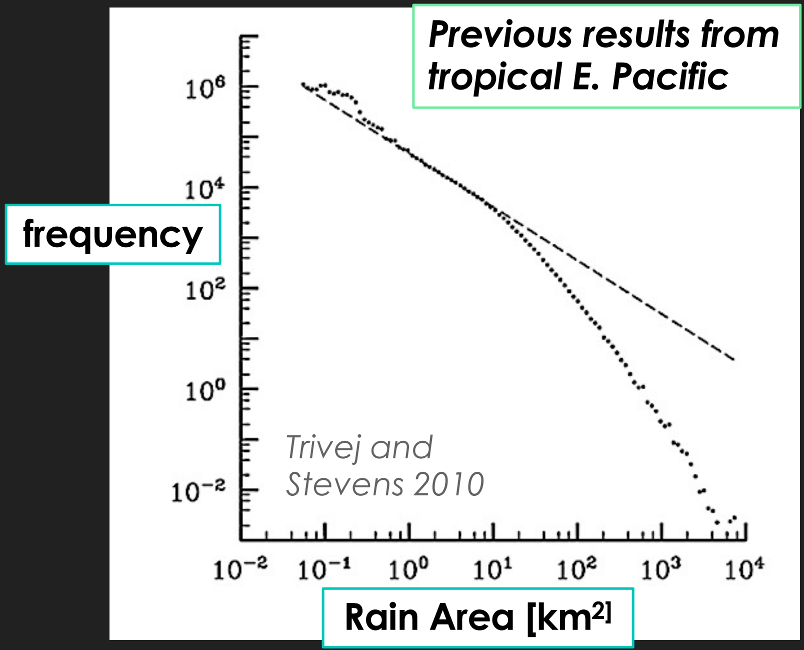
Motivation: most tropical oceanic rain events are smaller and more quickly evolving than satellite observation scales

Wilheit et al., 1991; Chiu et al., 1993; Kummerow, 1998, Viltart et al. 2006, Trivej and Stevens 2010, Xu and Rutledge 2014, Tan et al. 2017, Thompson et al. 2019

Passive microwave satellite beam width ~ 15-30 km; narrower rain features are missed in IMERG



Thompson et al. 2019, TOS



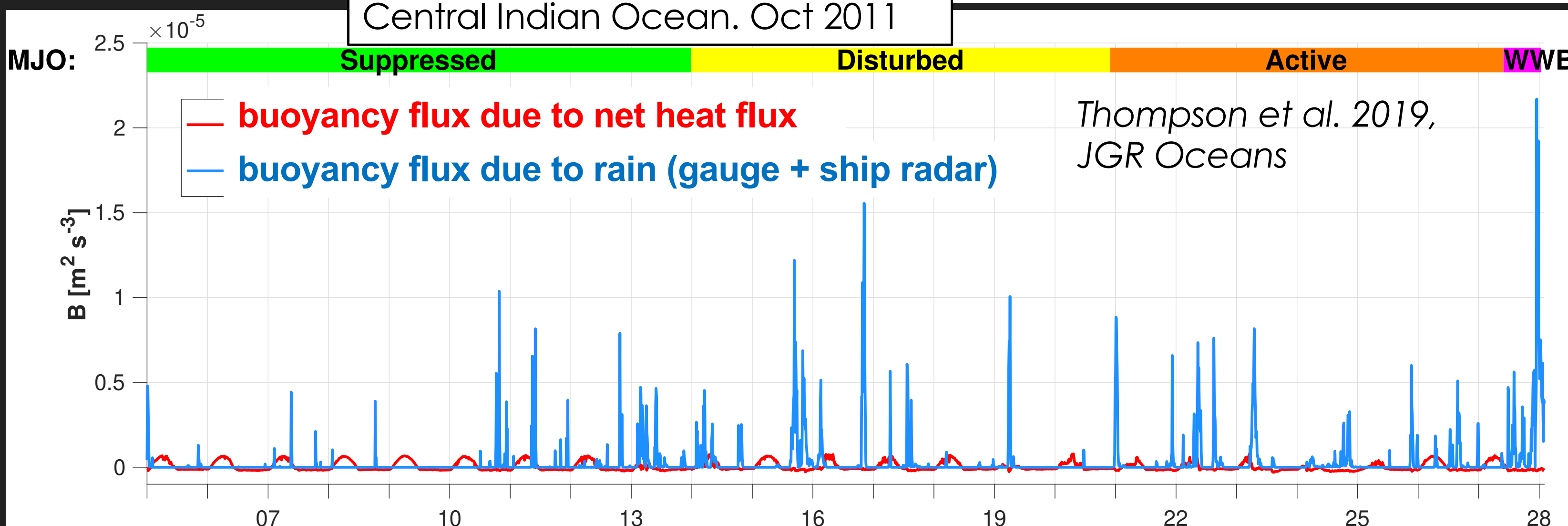
Rain stabilizes the ocean surface, decreases turbulent mixing and produces shallower ocean mixed layers

- A 10 mm h^{-1} rain rate produces as much buoyancy at ocean surface as maximum daytime solar heating in tropics; 200+ mm h^{-1} is regularly observed.

$$B = \frac{g}{\rho_W}\left[S_0\beta(P-E) - \frac{\alpha}{c_p}(Q_{\text{Lat}} + Q_{\text{Sens}} + Q_{\text{Solar}} + Q_{\text{IR}}) + \alpha\Delta TP\right]$$

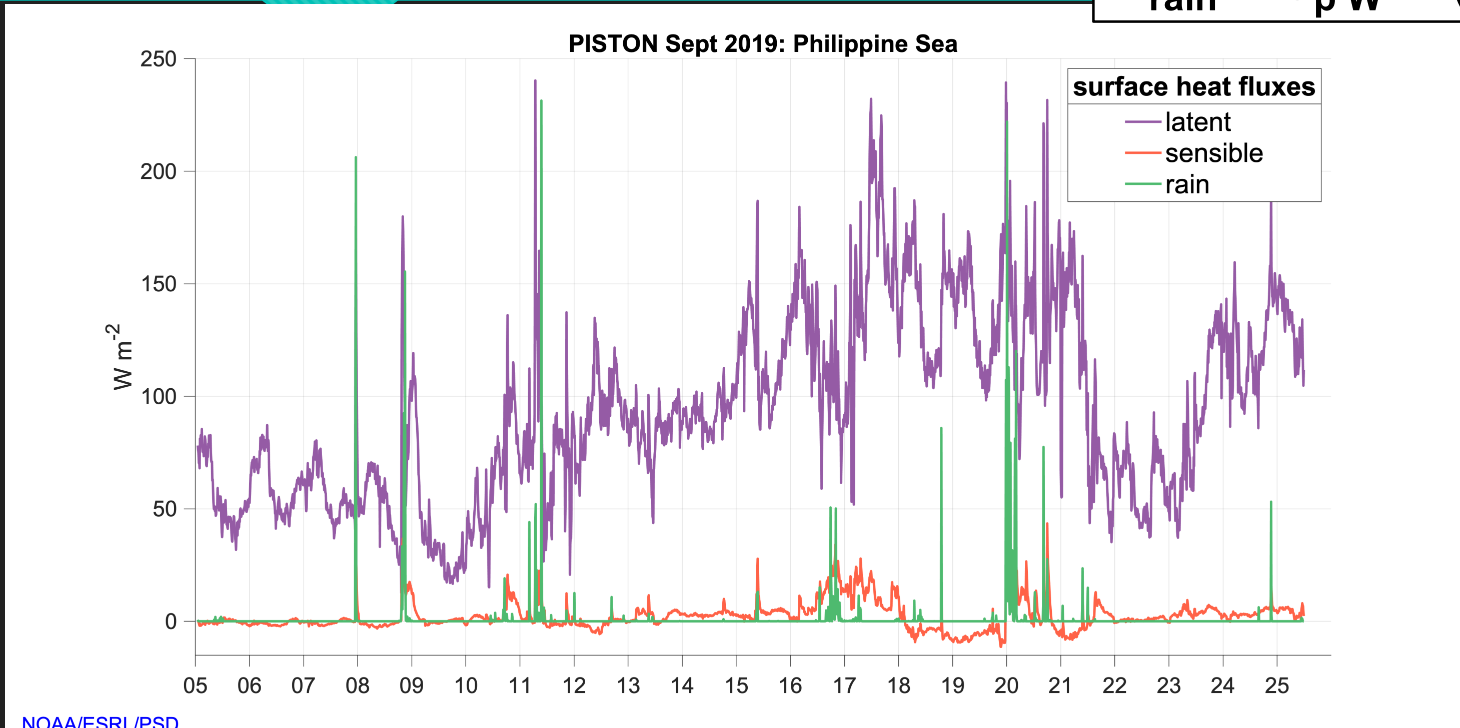
Rain Freshening and Evaporation Term	Heating Term	Rain Cooling Term

Central Indian Ocean. Oct 2011



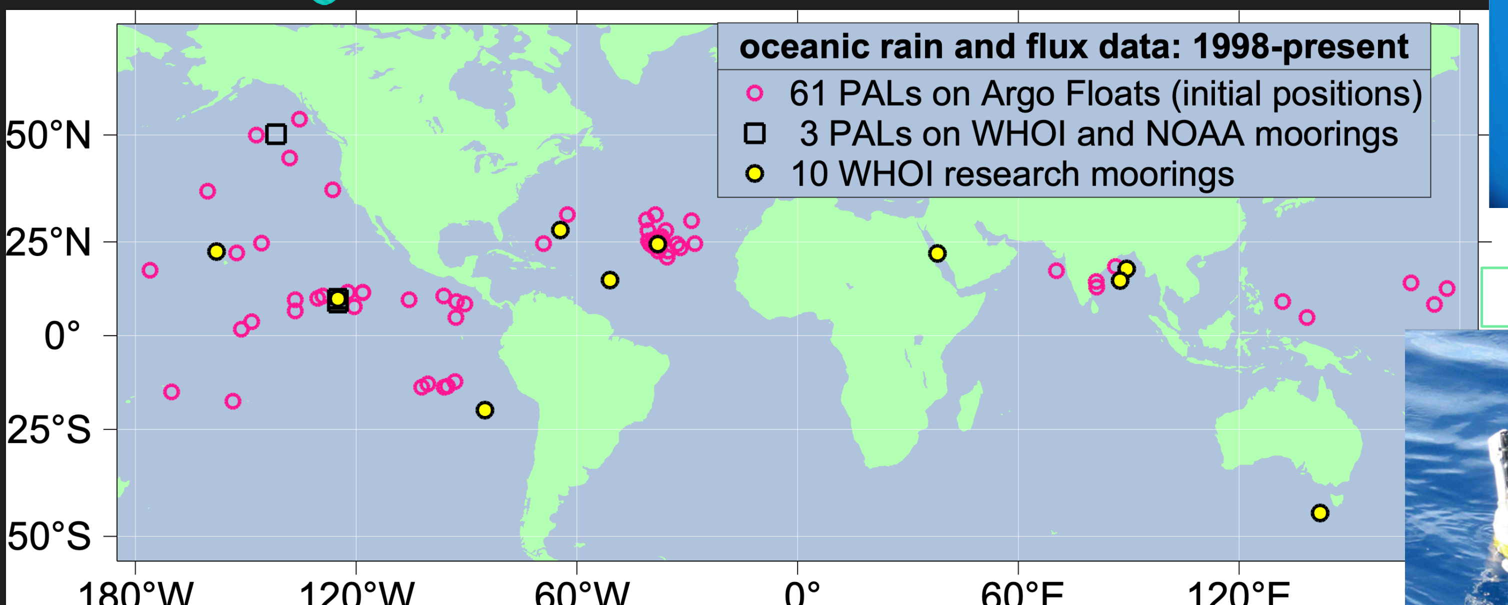
Flux of cool rain onto the ocean significantly enhances heating of the atmosphere

$$H_{rain} = c_{p\,W}\, P\, (T_W - SST)$$



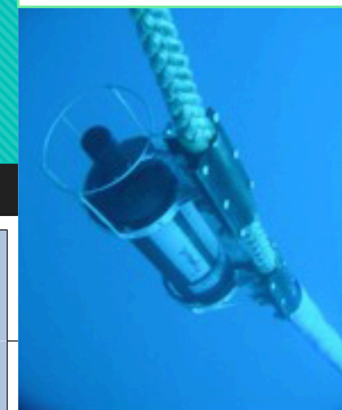
Gosnell et al. 1995, JGR

Objective 1a: produce rain and wind dataset from global array of acoustic sensors and moorings

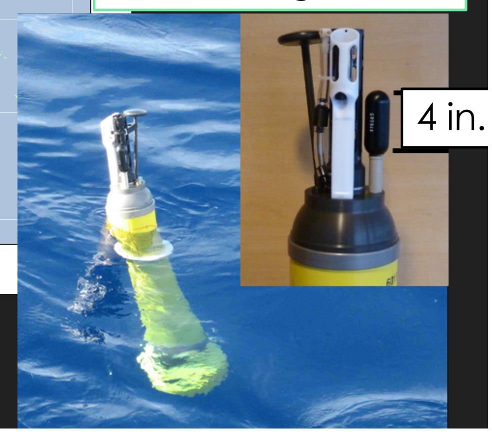


This "Ocean Validation (OV)" dataset will be provided to PMM science team

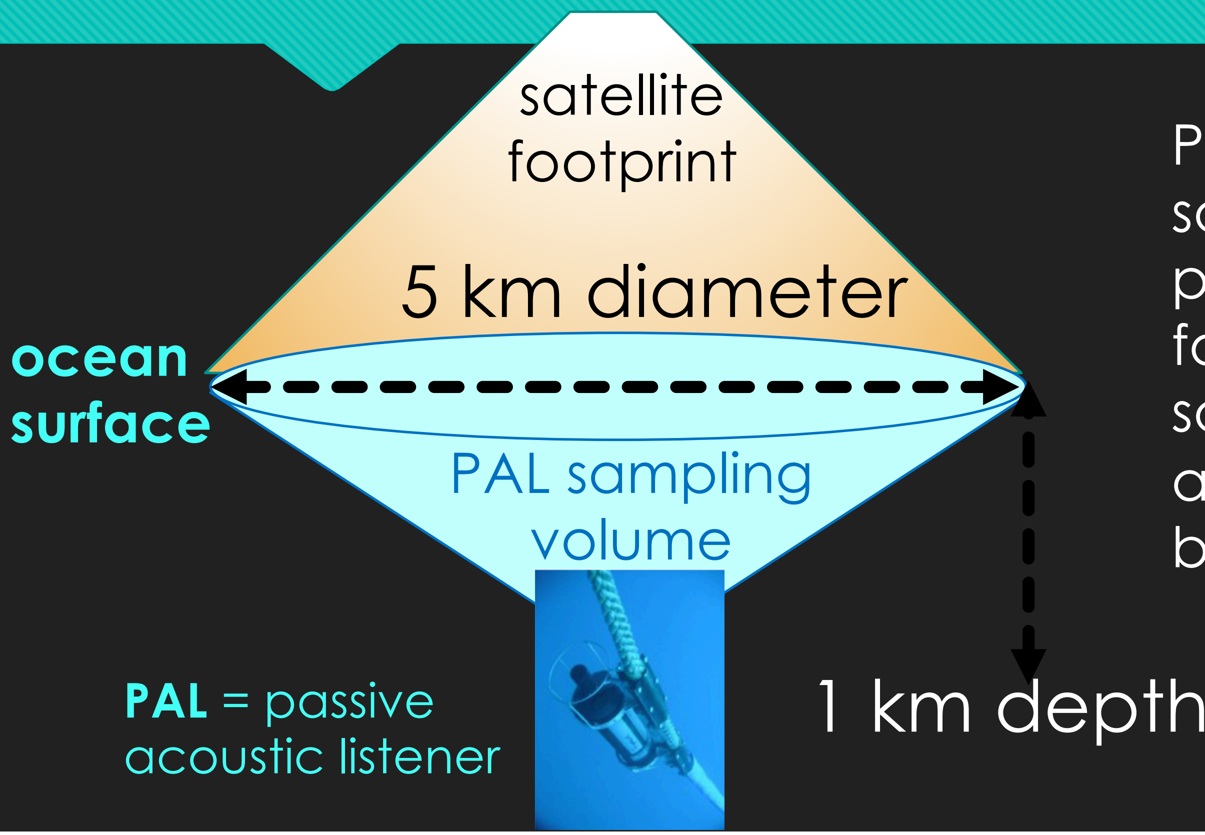
PAL on moorings



PAL on Argo floats



PAL's viewing diameter across the ocean surface is 5 × its depth



PAL's distributed sampling strategy provides an ideal means for comparison to satellite rain products and their downscaling; better than rain gauges

PAL produces excellent representation of instantaneous rain rate from serviced moorings

Yang et al. 2015, TOS

Visit Jie's poster tonight for more details!

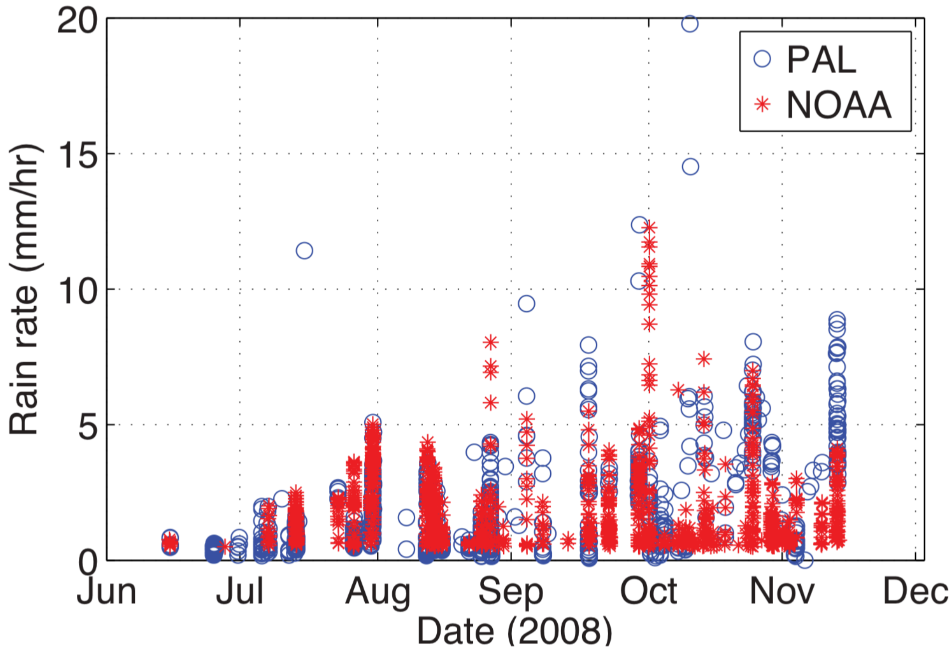


FIGURE 4. Comparison of six months of rain rates measured by a PAL deployed at Ocean Station P and by an in situ rain gauge mounted on the NOAA-Ocean Climate Station buoy at Ocean Station P.

PAL produces excellent representation of wind speed and accumulated rain from serviced moorings

Yang et al. 2015, TOS

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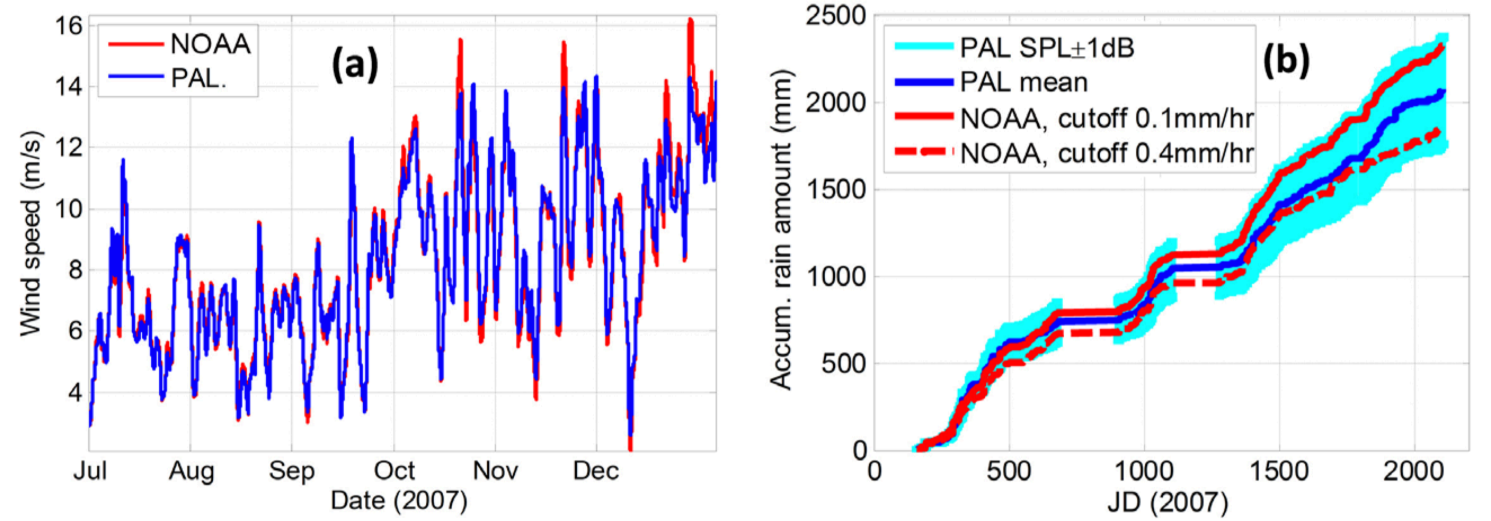
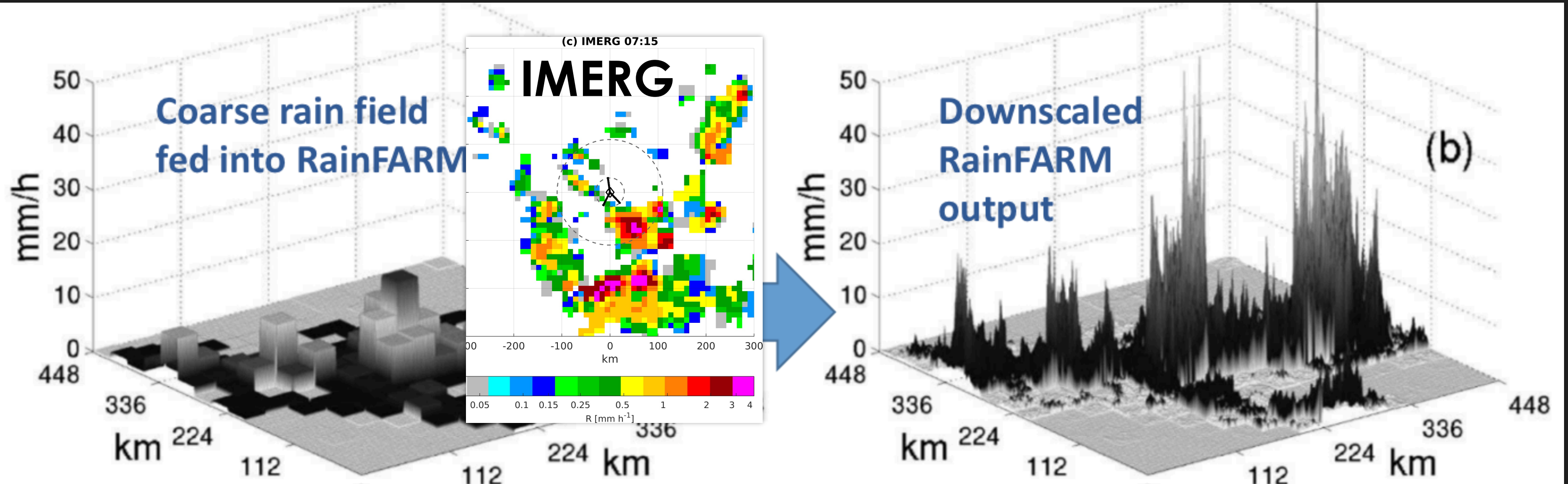


FIGURE 3. Comparison between PAL and NOAA buoy data collected at Ocean Station P for (a) wind speed, and (b) total accumulated rain from 2007 to 2012. In (b), the background cyan curve shows the uncertainty bounds of PAL estimates, and the blue is its mean curve. Because NOAA buoy data show clear noise, including negative rain rates, the data were cut off at 0.1 mm h^{-1} and 0.4 mm h^{-1} to calculate total rain amount to compare with PAL.

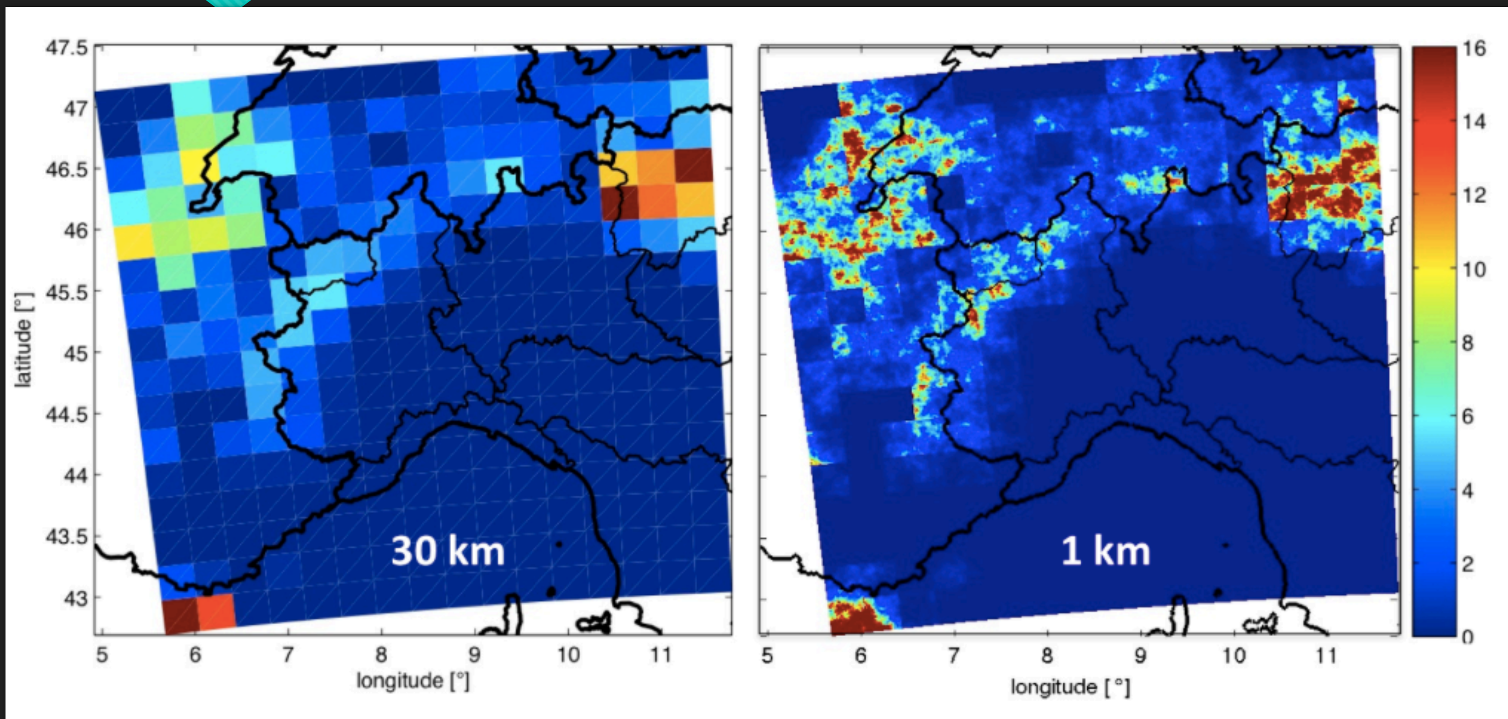
Objective 1b: downscale IMERG over locations of in-situ oceanic rain estimates

Downscale IMERG or its components from
30 - 10 km -> 5 km … 30 min -> 1-2 min



Adapted from R06 (Rebora et al. 2006a)

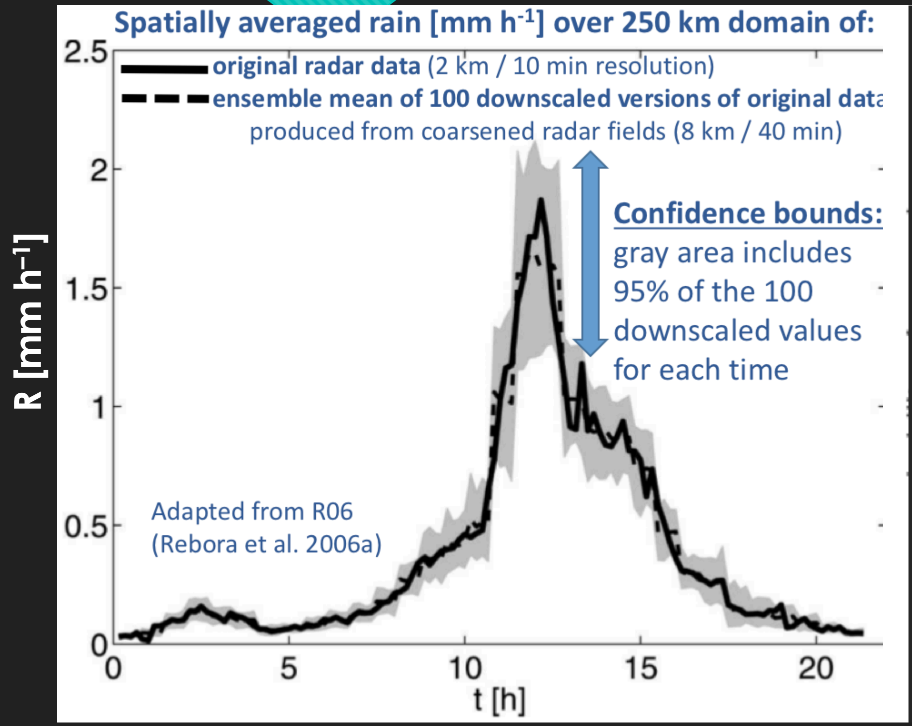
RainFARM downscaling technique can be applied in space, time, or both dimensions



rain rate

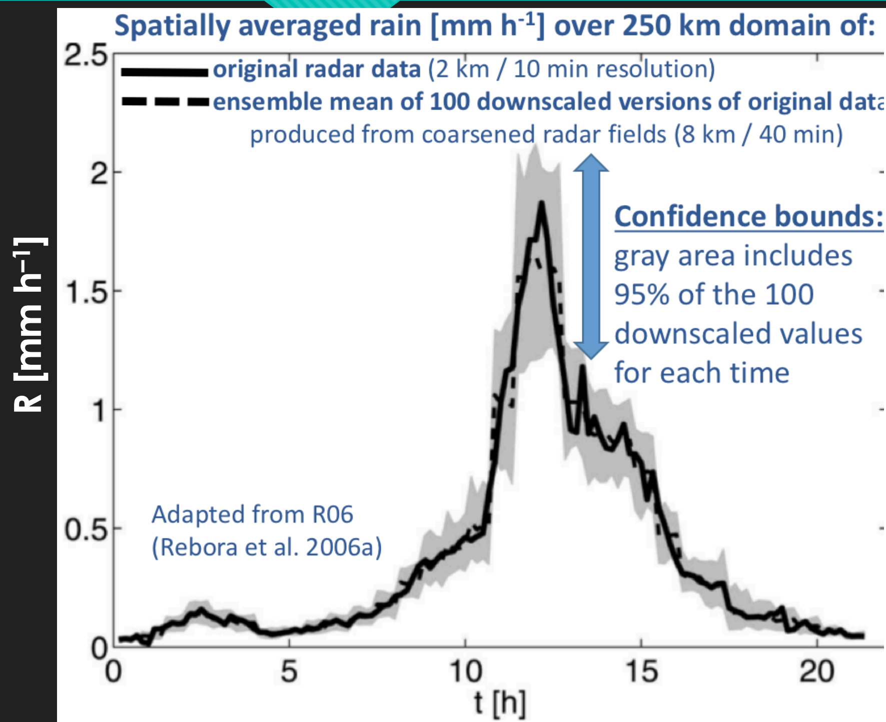
Rebora et al.

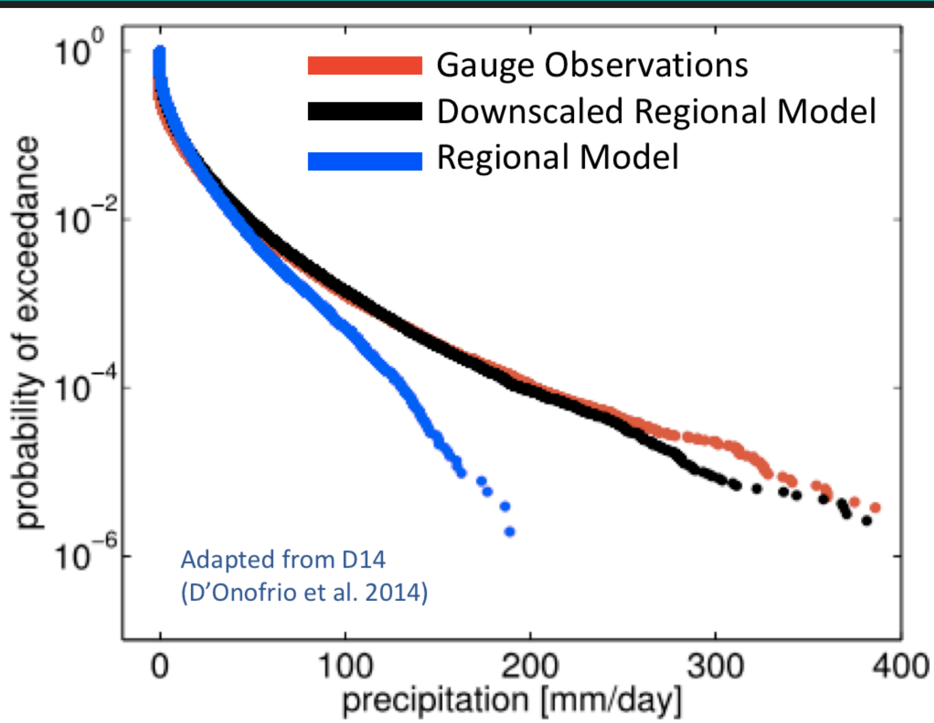
Objective 2: Compare in-situ acoustic rain dataset to original vs. downscaled IMERG



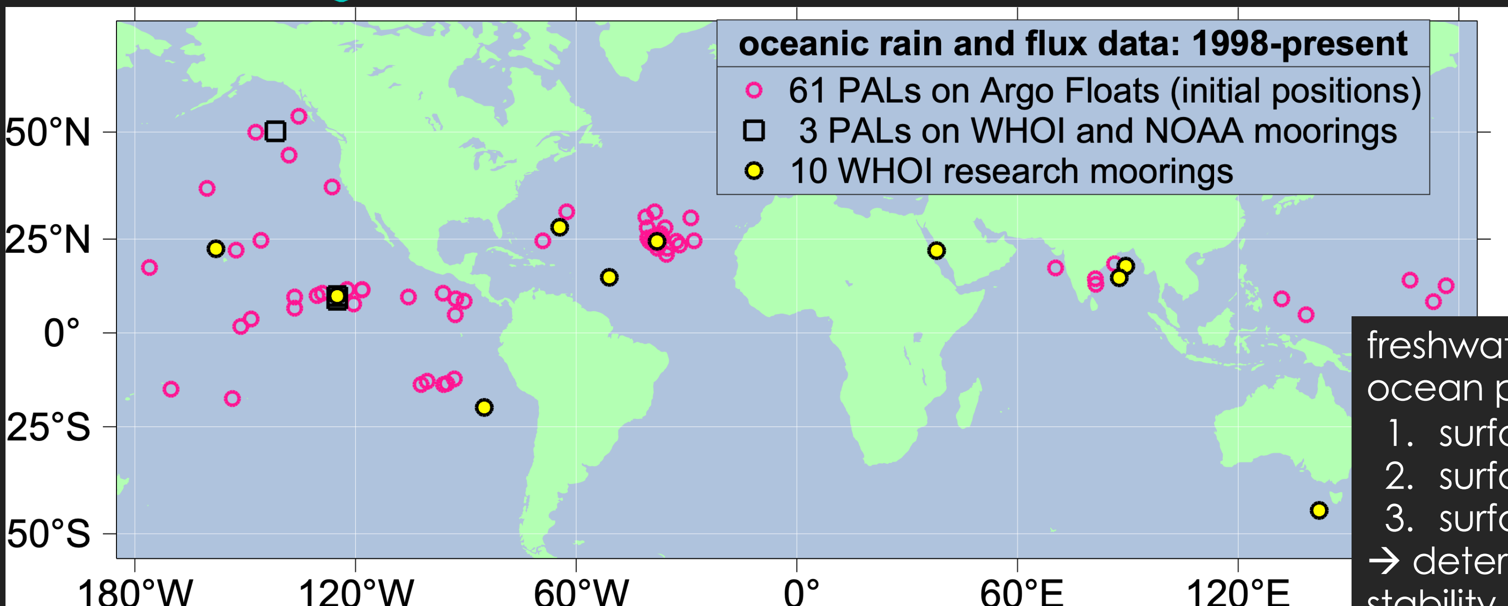
- **Comparisons:**
  - in different regions, seasons, and interannual states
  - as a function of atmospheric, oceanic, and rain characteristics.
  - characterize uncertainty
- Hypothesis: downscaled IMERG will improve characterization of in-situ rain

Objective 2: Compare in-situ acoustic rain dataset to original vs. downscaled IMERG





Objective 3: Use in-situ rain, downscaled IMERG, and original IMERG to estimate rain's impact on ocean.



Hypothesis: downscaled IMERG will improve air-sea flux estimates

freshwater fluxes into ocean produce significant:

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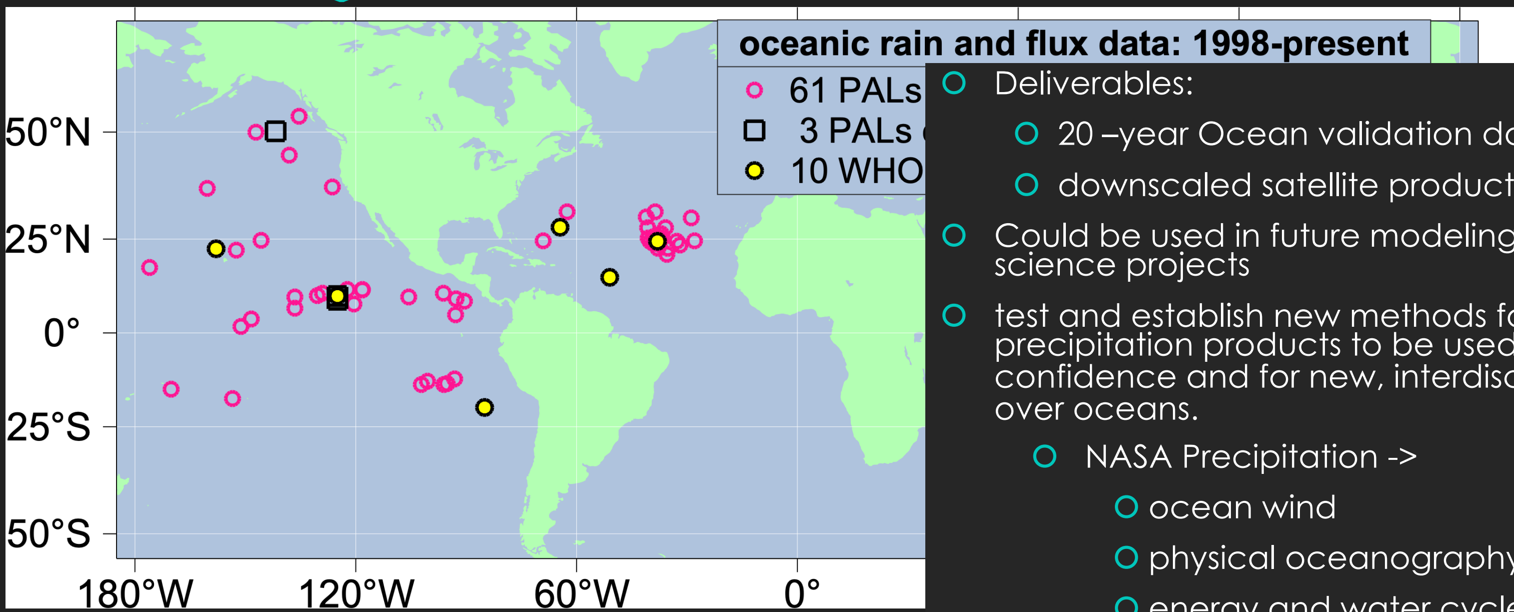
2. surface heat fluxes
3. surface buoyancy flux

→ determines ocean stability, mixing, heat content, surface energy budget

Relevance of Project and Deliverables



- Deliverables:
  - 20 –year Ocean validation dataset
  - downscaled satellite product… with uncertainty
- Could be used in future modeling, technical, and science projects
- test and establish new methods for satellite precipitation products to be used with greater confidence and for new, interdisciplinary purposes over oceans.
  - NASA Precipitation ->
    - ocean wind
    - physical oceanography
    - energy and water cycles
    - biogeochemical

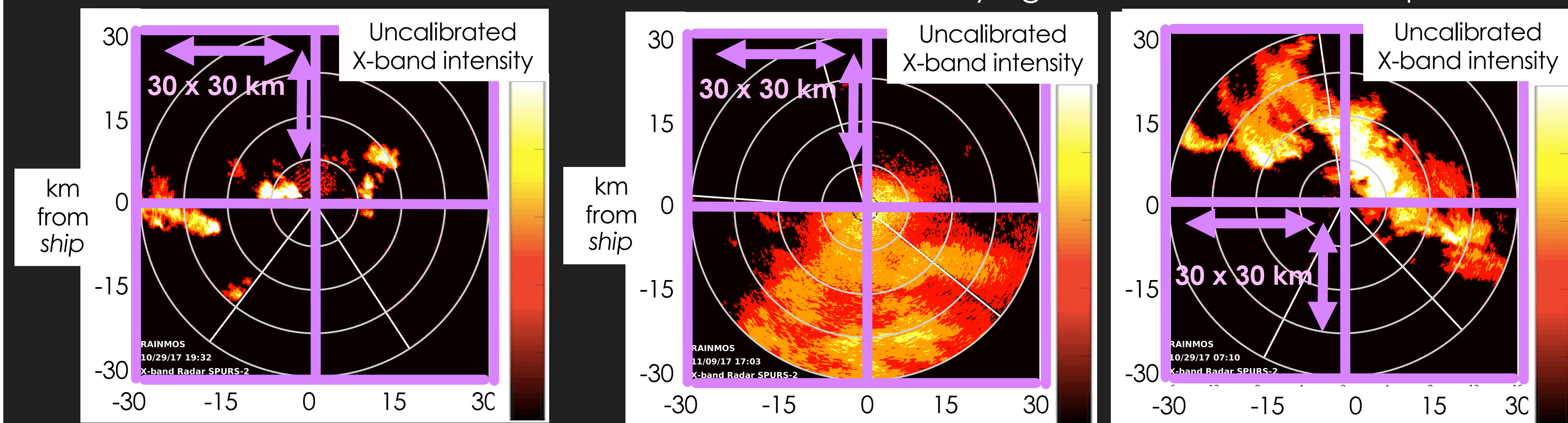
extra slides

Motivation: The majority of tropical oceanic rain events are smaller than satellite observation scales

Wilheit et al., 1991; Chiu et al., 1993; Kummerow, 1998, Viltart et al. 2006, Trivej and Stevens 2010, Xu and Rutledge 2014, Tan et al. 2017, Thompson et al. 2019

Rain features < 15-30 km in diameter are the most commonly-occurring events, but are often undetected by satellites*

Larger rain features > 15-30 km wide are detectable by satellite rain products and produce detectable surface salinity signals in SMAP/SMOS/Aquarius



Thompson et al. 2019, TOS

Project Relevance and Summary

- More comparisons and error estimates are needed between in-situ rain data and satellite rain products over ocean. This project will produce, analyze, and provide a global oceanic acoustic rain dataset for use by NASA-funded and other researchers.
- An existing, open-source downscaling methodology will be tested on IMERG for its ability to produce high-resolution rain rates and error characterizations of these estimates that are comparable to in situ rain measurements. These estimates and error characterizations are needed for future observational and modeling studies of precipitation dynamics and microphysics over oceans, and for understanding rain's impact on the atmosphere and ocean.
- The proposed research will test and establish new methods for satellite precipitation products to be used with greater confidence and for new, interdisciplinary purposes over oceans. This establishes a link between NASA PMM and other NASA programs such as biogeochemical and physical oceanography, energy and water cycle studies, and measurement of the ocean surface wind vector.

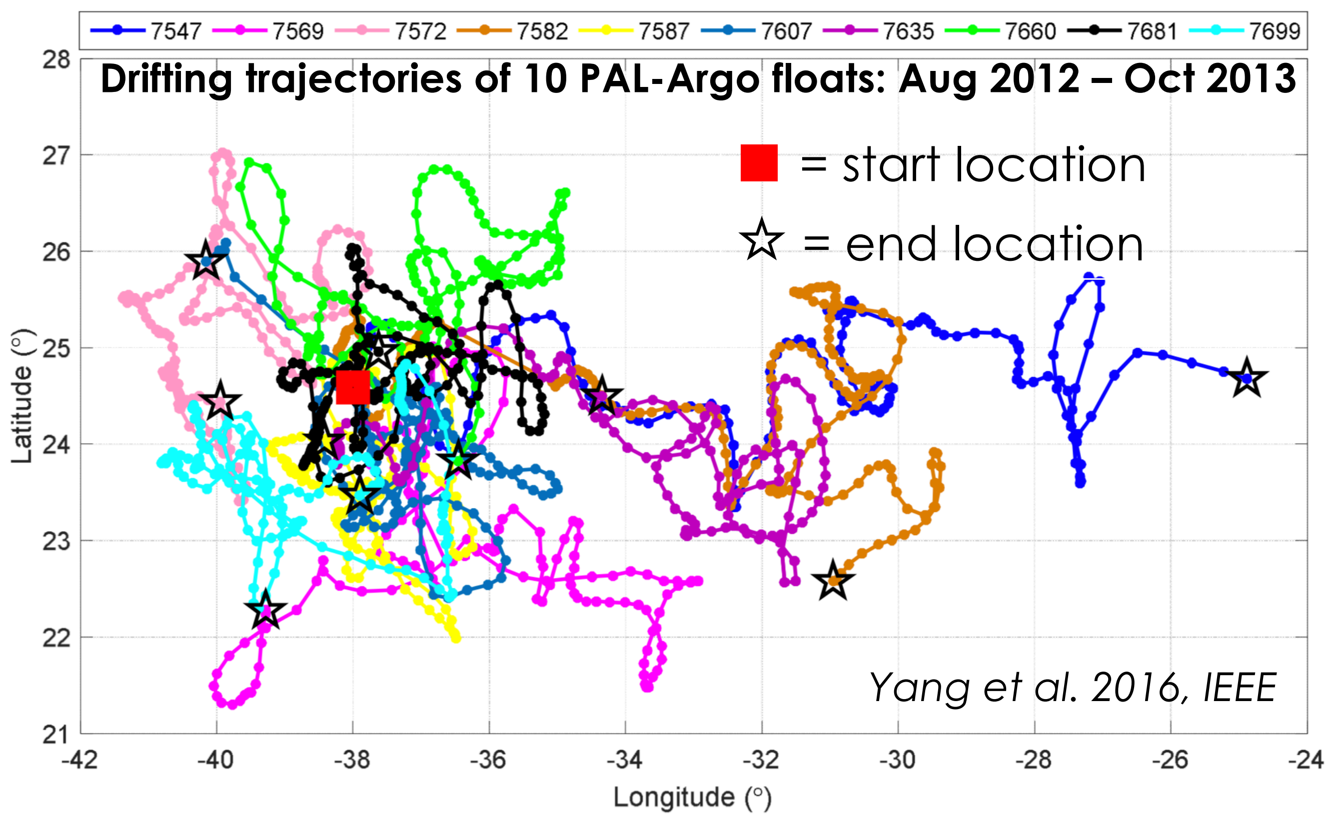
Technical Approach and Objectives

- **Objective 1:** Produce datasets of in-situ rain rate and wind speed from the 64 PALs deployed from 2004 to present day. Downscale IMERG to PAL spatiotemporal scales over the locations of 64 PALs and 11 research moorings.
  - acoustic estimates of rain rate and wind speed will be provided to the PMM science team for future *"Ocean Validation (OV)"* efforts of satellite rain products.
  - downscaling produces synthetic estimates of uncertainty ~ likelihood of the mean realization

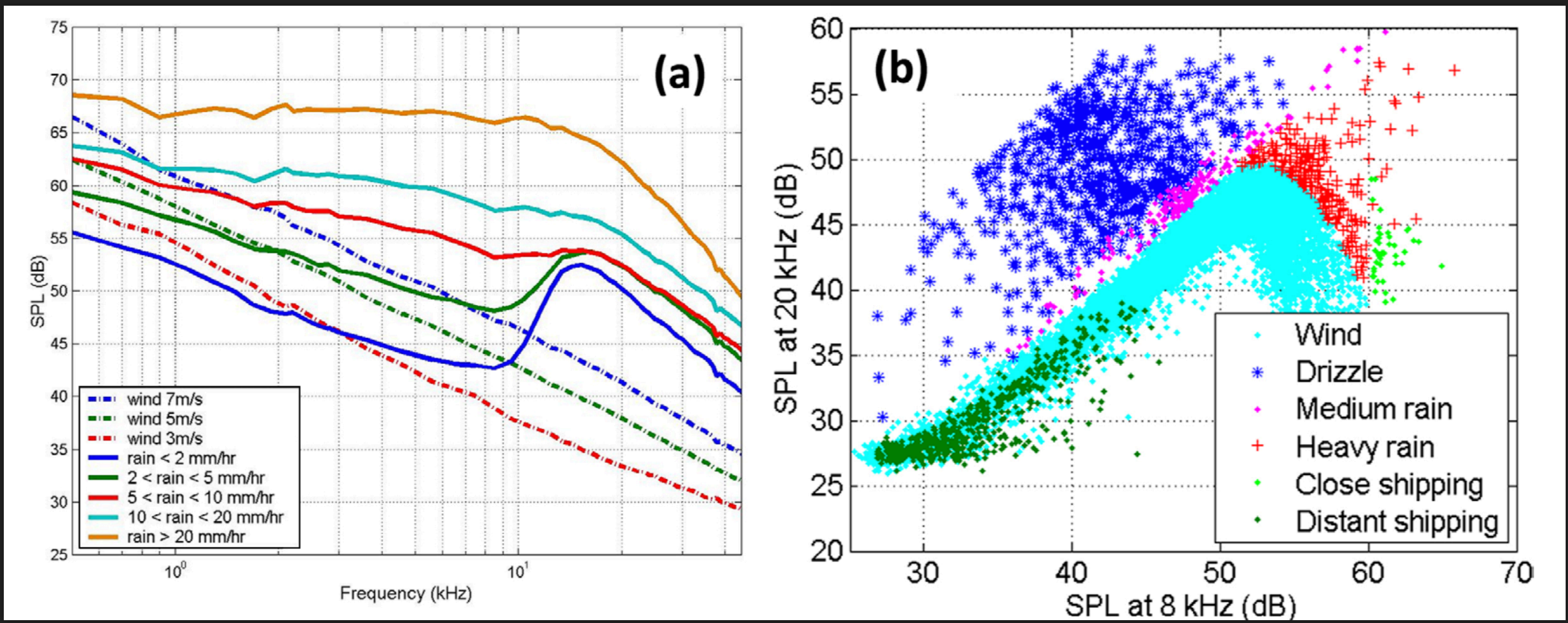
- **Objective 2:** Compare the PAL oceanic acoustic rain dataset to original and downscaled IMERG rain in different regions, seasons, and interannual states as a function of atmospheric, oceanic, and rain characteristics.
  - tests **Hypothesis 1:** *Downscaled IMERG rain fields can describe the magnitude and temporal variability of in-situ rain measurements over the ocean.*

- **Objective 3:** Using original and downscaled IMERG rain products, mooring gauge rain, and PAL rain at mooring locations, compare estimated and measured impacts of rain on air-sea interaction: ocean freshening, rain buoyancy flux, and rain heat flux.
  - tests **Hypothesis 2:** ***D****ownscaled IMERG rain ensembles can improve the depiction of rain impacts on surface heat and buoyancy fluxes and surface freshening compared to current IMERG products.*

PAL-Argos listen to rain and wind while drifting at 1km depth
→ 5 km diameter window of ocean surface…
then come up every 9 days to transmit data via Iridium



The PAL measures sound pressure levels from 0-50 kHz … to retrieve rain rate and wind speed



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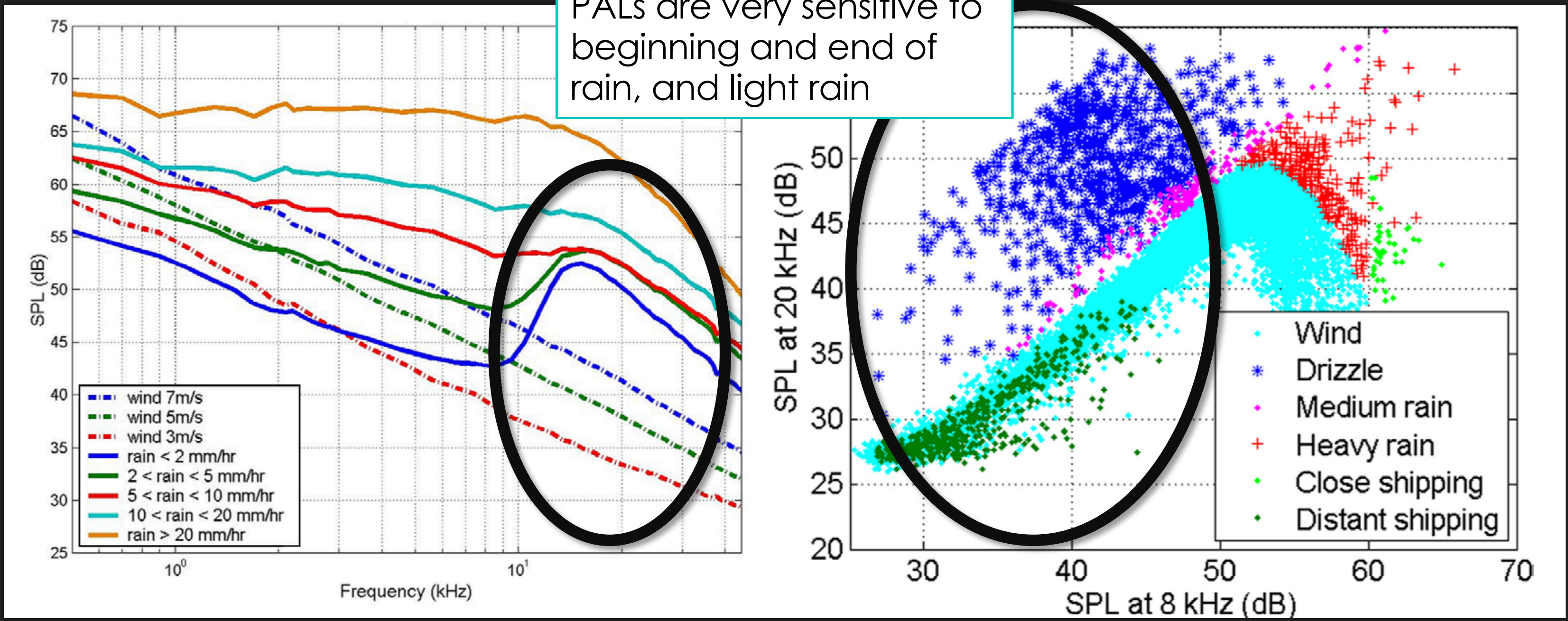
Drizzle is the loudest and most distinguished sound; PALs are very sensitive to beginning and end of rain, and light rain



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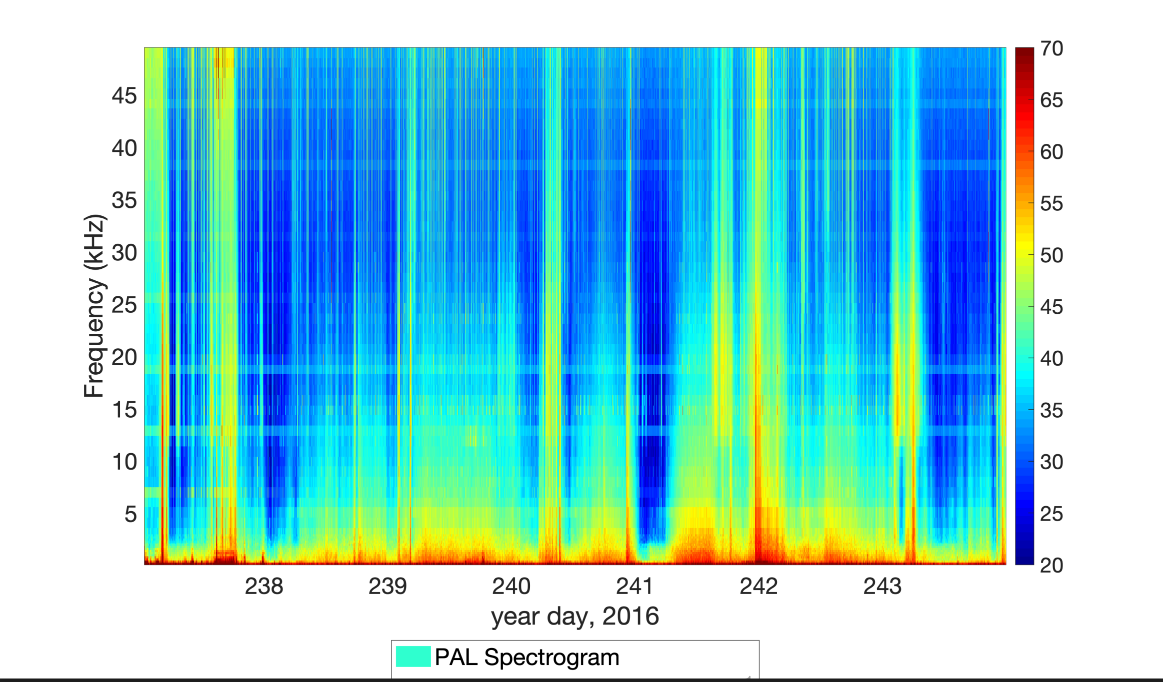

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